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ENHANCED HYPNOTIZABILITY BY CEREBRALLY APPLIED MAGNETIC FIELDS DEPENDS UPON THE ORDER OF HEMISPHERIC PRESENTATION: AN ANISTROPIC EFFECT

S. G. TILLER and M. A. PERSINGER

Behavioral Neuroscience Laboratory, Laurentian University

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A significant alteration in the hypnotizability of normal subjects after brief (15 min) exposures to weak (1 microT) pulsed magnetic fields over the temporal lobes was determined by the serial order of hemispheric stimulation. Only subjects who received the right hemispheric stimulation first displayed significantly elevated hypnosis induction profile scores (effect size equivalent to a correlation of 0.41). Implications for a technology that can: a) modify hypnotizability, b) encourage the consolidation of quasiexperiences that are reconstructed as autobiographical memory, and c) change the sense of self, are discussed.

Keywords: hypnosis induction, pulsed magnetic fields, hemisphere, acoustic chamber, phenomenology brain

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Adult human beings display a continuum of suggestibility or hypnotizability that can be defined as a propensity to experience enhanced imagery and affect (emotion) in response to contexts or to verbal instructions. During vulnerable periods these images may be so intense that they can be consolidated and later reconstructed as actual memories (Laurence & Perry, 1983; Labelle, Laurence, Nadon & Campbell, 1990). Because the person's sense of self is determined primarily by episodic memory, its modification by repeated suggestions from information (either cultural or clinical) upon which the person is highly dependent can change the person's identity and behavior (Persinger, 1993*a*).

Normal individuals consistently exhibit moderate, positive correlations between the numbers of complex partial epileptic-like signs (Persinger & Makarec, 1993) and objective measures of suggestibility and fantasy-prone behavior (Ross & Persinger, 1987). Indicators of lability or sensitivity of right temporal lobe functions rather than left temporal lobe functions are more significantly correlated with hypnotizability (Persinger, in press). These data are compatible with the concept (Horowitz & Adams, 1970) that electrical activation of the mesiobasal temporal lobe structures simply enhances the intensity (imagery) of the ongoing neurocognitive process.

We designed the following experiment in order to determine if hypnotizability could be modified by brief asymmetric exposures of the right or the left hemisphere to weak, pulsed magnetic fields. Time-varying magnetic fields applied across the temporal lobes should induce weak currents within regions that exhibit the lowest electrical thresholds (such as the amygdala and hippocampus). The intermittent component was employed to attenuate the habituation that normally accompanies protracted stimulus presentations (Persinger, 1974).

Correspondence to: Dr. M. A. Persinger, Behavioral Neuroscience Laboratory, Department of Psychology, Laurentian University, Sudbury, Ontario P3E 2C6.

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If: 1) suggestible individuals are prone to modification of episodic (autobiographical) memory (Labelle, Laurence, Nadon & Campbell, 1990), and 2) alterations in episodic memory can alter the person's concept of self, then techniques that enhance suggestibility could be employed to facilitate this change in autobiographical memory and (consequently) in self-definition. Technology that allows the modification of the memory of the person's past or its proclivity to be influenced by exogenous stimuli without awareness of this modification would constitute a significant and powerful form of cognitive control and therapeutic intervention (Persinger, 1993*b*).

METHOD

Subjects

A total of 18 men and 18 women, who were registered in first year psychology courses, volunteered as subjects; their ages ranged between 18 and 46 years (mean = 22). Their participation was rewarded by a 2% bonus mark.

Method

About one month before the experiment began, the subjects had completed the Personal Philosophy Inventory (PPI) during a class period. This inventory contains items that reflect a continuum of complex partial epileptic-like experiences (Persinger & Makarec, 1993) as well as a cluster of items that serve as controls for yes responding.

On the day of the experiment, each subject was tested singly. The subject sat in a comfortable chair that was housed within a commercial acoustic chamber. After each half of a pingpong ball (filled with cotton) had been placed over the eyes, a standard motorcycle helmet was placed over the subject's head. A cluster of four solenoids had been embedded within the helmet along each of the two temporal planes. A small red photographic developing light was the only background source of illumination. The subject could communicate with the experimenter through a lapel microphone and had been told that he or she could terminate the experiment and leave the setting at any time.

After the doors of the acoustic chamber had been secured, the magnetic fields were generated according to procedures that have been published previously in this journal (Richards, Persinger & Koren, 1993). Essentially, a preconstructed wave form was generated by a PC computer, amplified and applied through a commutator to each of the four pairs of solenoid that were embedded in the helmet. Each pair of solenoids was activated for 0.5 sec by a Gerbrands 300 series sequencer such that a full spatial cycle (ellipsoid pathway) required 2 sec.

Unlike the previous studies (Persinger, Koren, Makarec, Richards & Youlton, 1991; Richards, Persinger & Koren, 1993; Ruttan, Persinger & Koren, 1990), the delivery of the current was modified so that it generated the magnetic field primarily from either the right or the left side of the helmet. The wave pattern was selected on the basis of its stimulatory characteristics (Persinger, et al., 1991). Its structure employed a series of sinuosoidal oscillations (equivalent to about 10–12 Hz) whose amplitudes successively increased and was similar to the one represented in Figure 1B (Richards et al., 1993). This pattern was presented for 0.6 sec. once every four sec. for a total of 15 min. A Metex 3800 multimeter and magnetic sensor (probe) indicated that the activation of the right cluster of solenoids produced a field strength of approximately 10 mG (1 microT) within the estimated volume of

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temporal cortices and a field strength of approximately 1 mG (0.1 microT) within the homologous region of the left side; the variability within this space was +/−10%. Activation of only the left solenoids produced a similar but symmetrically opposite gradient in intensity.

Each subject received 15 min of stimulation to the left and to the right temporal lobes. Half of the numbers of subjects (men and women) were stimulated first over the left and then over the right hemisphere while the remaining subjects received the opposite pattern. Immediately after the termination of each magnetic field application, the experimenter entered the chamber and removed the eye-coverings. The subject completed the Exit Questionnaire and was then administered Spiegel and Spiegel's (1978) Hypnosis Induction Profile (HIP). The HIP is a performance-based index of suggestibility whose composite scores range from 0 to 10. The Exit Questionnaire (Persinger, et al., 1991) is composed of 20 items (0 = never, 1 = at least once, 2 = frequently) that reference the most common types of experiences that occur within this context. It also contained a "pleasantness of experience" rating that ranged from – 2 (very unpleasant) to + 2 (very pleasant). Specific items that were employed to support construct validity included optic sensations: a) primarily in the upper visual field (no, yes), b) within the left visual field (no, yes) or c) within the right visual field (no, yes).

After the HIP had been administered, the goggles were replaced and the same magnetic stimulation was applied to the other hemisphere for that subject. At the end of the 15 min. period, the experimenter entered the chamber and removed the goggles. The subject once again completed the Exit Questionnaire and was then administered the HIP. The subject then left the experimental setting. All subjects were tested in a random order by an experimenter who was not familiar with the hypothesis of the study.

The two HIP scores, pairs of 20 items from the Exit Questionnaire, and the composite scores for the complex partial epileptic-like signs and control clusters for each subject were loaded onto a VAX 4000 computer. The primary analysis was a three-way analysis of variance with one level repeated (the two HIPs) and two not repeated (order, i.e., left hemisphere first and right hemisphere second vs right first, left second) and sex. In order to discern the neurocognitive source for any possible effect, variables that have been *a priori* associated with hypnotizability, i.e., complex partial epileptic like signs and "feelings of vibrations moving through the body" were employed as specific covariates. Control covariates, which involved non-specific experiences that should not be strongly associated (or causal) with hypnotizability, included scales that contained estimates of the pleasantness of the experience, the average rating of all experiences within the chamber and clusters of control items (yes responding) from the Personal Philosophy Inventory.

The secondary analyses, which were exploratory, involved three way analyses of variance with each of the questions that followed the transcerebral stimulation (the 20 items from the Exit Questionnaire). Because of the number of items within the Exit Questionnaire, factor analysis was performed (principal components) to determine the primary source of variance; the factor scores were also analyzed as a function of the experimental treatment. All analyses, e.g., MANOVA (multivariate analyses of variance), post hoc paired t-tests, involved SPSS software.

RESULTS

The means and standard deviations for Spiegel and Spiegel's Hypnosis Induction Profile (HIP) for the groups that received the pulse-fields either to the right or to the left temporal

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lobes either during the first or during the second presentations are shown in Table 1. According to the repeated measure analysis of variance (MANOVA) there were no statistically significant order [F(1,27) = 0.23, p > .05], sex [$F(1,27) = 1.04$, $p > .05$] or order by sex [F(1,27) = 0.19] effects. There was a statistically significant hemispheric order by repeated (HIP) measure interaction [$F(1,27) = 5.69$, $p < .05$; eta = 0.41] but neither a sex by repeated measure nor a three-way interaction (all $Fs < 1.00$]. *Post hoc* analysis indicated that the source of the interaction was the significantly higher hypnotizability for subjects after they had received magnetic field stimulation over the right temporal lobe *first* compared to the other three conditions that did not differ significantly from each other.

The strength of the effect due to the temporal order of the two presentations of the magnetic fields over the hemispheres (right-left vs left-right) upon the HIP scores was not eliminated when the following variables were covaried (F scores for the interaction between the HIP and the order of hemispheric stimulation *after* covariance for the indicated variable are indicated in parentheses): complex partial epileptic-like signs [$F = 4.87$, $p < 05$], control (yes) responses from the PPI [4.87, $p < .05$], and mean pleasantness rating of the experiences within the chamber [$F = 5.69$, $p < .05$].

Although the average intensity of all experiences within the chamber during stimulation was associated with the HIP scores [$F = 9.34$; $r = 0.51$, $p < .01$], covariance for this association did not affect the statistical significance of the interaction [$F = 5.69$, $p < .05$]. Covariance for the largest (first) factor of the experiences within the chamber during magnetic field stimulation, which was composed primarily (r loading values > 0.50) of reports of: a) tingling sensations, b) ego-alien intrusive feelings, c) fear or terror and d) being "somewhere else", actually *enhanced* the magnitude of the hemispheric order by hypnotizability interaction [$F(1,26) = 12.49$, $p = .002$; eta = 0.56]; scores for this factor were significantly correlated ($r = 0.50$) with the person's hypnotizability. However the significance of this interaction was eliminated when the specific variance associated with the intensity of "vibrations moving through the body" was first removed (covaried) from the analyses [$F = 2.84$, $p > .05$; eta = 0.30); these vestibular experiences were positively (beta = 0.41) associated with the HIP scores.

The results of the secondary (exploratory) analysis revealed no significant order effects for the following items from the Exit Questionnaire (means and standard deviations for the combined scores are given): sense of a presence 0.1 (0.3), out-of-body experience 0.2 (0.3), childhood memories 0.2 (0.4), dream-like experiences 0.3 (0.4), tingling sensations 1.0

TABLE 1
Means and standard deviations for the Hypnosis Induction Profile (HIP) and ratings of subjective experiences after exposure to the pulsed magnetic field after opposite orders of stimulation over the temporal lobes

Measure	Order 1				Order 2			
	L first		R second		R first		L second	
	M	SD	M	SD	M	SD	M	SD
HIP	5.4	3.1[a]	5.0	3.4[a]	6.2	3.4[b]	5.4	3.2[a]
Vivid Images	0.4	0.6[a]	0.7	0.8[b]	0.4	0.5[a]	0.3	0.6[a]
Pleasant Vibs	0.8	0.8[a]	0.7	0.8[a]	0.8	0.8[a]	0.4	0.6[b]
Sadness	0.2	0.5[a]	0.1	0.5[a]	0.4	0.5[b]	0.1	0.3[a]
Recurrent Idea	1.1	0.7[b]	0.7	0.6	0.6	0.8	0.6	0.8[a]
Time Passage	0.6	0.5[a]	0.9	0.3[b]	0.8	0.3	0.8	0.3
Total Rating	0.9	0.9	0.9	0.8	1.0	1.0	1.4	1.5

a vs b = p < .05.

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(0.7), anger 0.1 (0.2), sadness 0.2 (0.4), fear 0.1 (0.4), odd smells 0.1 (0.2) odd tastes 0.2 (0.4), spinning sensations 0.4 (0.5) and feeling as if somewhere else 0.4 (0.6). There were significant treatment differences for the intensity of occurrence of vivid images, the reoccurrence of the same idea and vibrations within the body. The means and standard deviations for these measures are also shown in Table 1.

Subjects who received right hemispheric stimulation after left hemispheric stimulation reported more vivid visual images during this episode than did the subjects who received the stimulation in the opposite order. However subjects who received the left stimulation first experienced the recurrence of the same idea during this period. Occurrences of vibrational experiences were significantly attenuated only if the left hemispheric stimulation occurred after the right hemispheric stimulation. Finally, the only significant emotional experience that was disproportionately induced by anistropic stimulation of the two hemispheres was sadness. It was more prevalent during both periods of stimulation if the right hemisphere had been stimulated first. Subjects who had received the left hemispheric stimulation first reported a significantly [$F = 4.22$, $p < .05$] more frequent average incidence [30% (40%) of visual sensations along the *right* visual field relative to the subjects who received the right hemispheric stimulation first [10% (10%)]. For comparison the average incidences of visual experiences along the left peripheral visual field for the two orders of magnetic field presentation (n.s.) were 20% (30%) and 15% (30%), respectively.

DISCUSSION

The general strategy of inserting neurocognitive information into concomitant brain activity by applying weak but complex magnetic fields requires the isolation of the relevant wave structure rather than an incessant focus upon the intensity of the force. The principle is most evident when applied to an analogous problem: sonic energy. If a pure, 1000 Hz sine wave were generated for a protracted period, there would be minimal organismic response unless the intensity surpassed some nociceptive threshold, e.g., 100 db. However, with much lower intensities, such as 30 db, a complex wave containing the meaningful information "help me" could evoke significant and powerful changes within the person who is exposed to that energy.

Several studies by Sandyk and his colleagues (Sandyk et al., 1991; 1992) have indicated that brief exposures to extremely low frequency magnetic fields within the picoT range alter disease states. We (Persinger, et al., 1991; Richards, et al., 1993) have found that application (across the temporal lobes) of 1 microT (10 mG) magnetic fields with burst firing-like wave structures can generate conscious experiences that reflect activation of the appropriate left or right hemisphere. Application of slightly more intense 4.5 Hz spike-like fields to the left hemisphere evoked a greater disruption in the consolidation of a concurrent standardized narrative than stimulation along the right hemisphere (Persinger & Nolan, 1985). In all of these studies, the complexity or the relevancy of the "information content" of the wave structure to the targeted "neural network" (John, 1990) appears to have been more important than the intensity of the field once a critical threshold had been achieved.

The present study was designed to help determine the etiology of a common clinical observation. Mildly depressed (adult) patients whose brains have been stimulated by the procedures similar to those that were employed in this study appear more compliant to subtle suggestion during the first 5 to 10 minutes after the termination of the exposure. Several years ago DeSano and Persinger (1987) reported that exposures to 1000 mG, 1 Hz to 4 Hz,

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sinusoidal magnetic fields that were bilaterally applied across the temporal lobes quantitatively enhanced the hypnosis induction profile. Subsequent analyses and experimental work have indicated that the homogeneous application of these fields may have simply exacerbated the subject's own intrinsic but subtle asymmetries of hemispheric activity.

The hypothesis that the hemispheric order of stimulation with the relevant magnetic field stimulus, i.e., a right to left order, would evoke a transient increase in hypnotizability was also derived from frequent clinical observations. First, there is usually a right parietotemporal stimulation that can range from repetitive, light tactile stimulation of the subject's *left* hand to passive visual pursuit of a swinging pendulum or horizontally moving focus (which preferentially activates Brodmann areas 18 and 19). After this process, there is usually emphasis upon verbal (left hemispheric) and strongly metaphorical instruction that amplifies subjective imagery (Brigham, 1994).

Commensurate with this predicted anistropic effect, subjects who received stimulation to the right temporal region first, displayed a greater suggestibility than those who received the same stimulation first to the left hemisphere. That the effect was transient or was inhibited by the subsequent stimulation of the left hemisphere by the same pulsed magnetic fields was indicated by the loss of the relatively enhanced suggestibility whose absolute values were similar to those recorded following left hemispheric stimulation. Consequently we cannot determine the duration of the persistence of the alteration in suggestibility. The fact that the experimenter was not familiar with the hypothesis minimized the possibility of non-specific cues or bias.

The persistence of the significant order effect even after covarying for the subject's inferred temporal lobe sensitivity, (as defined by their complex partial epileptic-like signs), indicates that the applied field did not operate through neurocognitive processes with which this phenomenology is shared. However the elimination of the statistical significance of this effect when the relative intensity of "vibrations moving through the body" (reported after the magnetic field stimulation) was covaried, suggests that the hypnotizability and the capacity to experience these vibrations may share a similar source of neurocognitive variance; associations of similar magnitude and direction have been reported previously (Ross & Persinger, 1987). Traditional neuroscience indicates that these experiences should involve the medial surfaces of the transverse gyri of the temporal lobes (Crosby, Humphrey & Lauer, 1962). Because neither experiences of "spinning" nor "dizziness" affected the statistical significance of the order by hypnotizability interaction, the association between magnetic field stimulation, "body vibrations" and hypnotizability is not likely to be due to a nonspecific influence.

Concomitant experiences that suggest the actual induction of hemispherically-appropriate experiences (Budzynski, 1986; Goldberg, 1981) by the applied fields were indicated by the results of the exploratory analyses. Only those subjects who received the stimulation of the left temporal region (first) reported the experience of a "recurrent idea"; these same subjects reported a marked enhancement of visual images during right hemispheric stimulation but only after the left temporal lobe had been activated. The conclusion that stimulation of the left hemisphere generated compatible experiences (typically associated with its activation) (Budzynski, 1986) was indicated by the greater awareness of the passage of time and the experience of more visual sensations along the right (contralateral) visual field. These experiences did not occur when stimulation across the hemispheres was given in a reverse order. The possibility that these effects were due to a generalized increase in report frequency is not likely because the average ratings of subjective experiences did not differ between treatments.

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We have found that the affective (emotional) dimensions of words that are employed to describe thoughts and experiences during exposure to burst-firing magnetic fields can be modified without the subject's awareness (Richards et al., 1993). Although the content of the imagery that is evoked during stimulation by exogenous complex magnetic fields reflects the person's reinforcement history, the themes (e.g., visual, olfactory, vestibular) should be associated with the focus of the field's application. In light of the present results we hypothesize that experiences of specific themes can be induced within subjects by applied magnetic fields whose temporal structures are resonant with specific regions; these experiences, because of the concomitantly enhanced suggestibility and imagery, might be later reconstructed as actual memories. The clinical application of such an effect would be significant.

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